VLSI Based Fluid Flow Measurement Using Constant Temperature Hot Wire Anemometer

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Abstract— The performance of a hot-wire anemometer configuration is affected by variation in the fluid temperature. The classical temperature compensation techniques in such anemometers employ two sensors. The performance of a temperature- compensated hot-wire anemometer configuration using a single sensor alternating between two operating temperatures and proposed for constant fluid velocity is investigated under conditions of time-varying fluid velocity. The measurement error introduced is quantified and can be practically eliminated using a low-pass digital filter.

Keywords— Electrical equivalence, fluid temperature compensation, hot-wire anemometer and thermoresistive sensor, measurement error,op-amp,CMRR.

INTRODUCTION

Constant Temperature hot-wire anemometer (CTA) circuit based on a feedback self-balanced Wheatstone bridge containing a thermo-resistive sensor is known to exhibit a relatively wide bandwidth [1]. The compensation of the effect of fluid temperature T_f is usually done by employing an independent fluid temperature sensor [1]–[5] or two similar feedback bridge circuits with two identical sensors operating at two different constant temperatures [6]. The finite nonzero amplifier input offset voltage does not permit the sensor temperature to remain constant with varying fluid velocity [7]. This offset voltage also affects the dynamic response of the feedback circuit. The circuit temporal response is slower for a higher offset voltage. Further, it has been shown that when the amplifier input offset voltage is zero, or below a critical value, the circuit becomes oscillatory.

Thermal anemometry is the most common method used to measure instantaneous fluid velocity. The technique depends on the convective heat loss to the surrounding fluid from an electrically heated sensing element or probe. If only the fluid velocity varies, then the heat loss can be interpreted as a measure of that variable.

Thermal anemometry enjoys its popularity because the technique involves the use of very small probes that offer very high spatial resolution and excellent frequency response characteristics. The basic principles of the technique are relatively straightforward and the probes are difficult to damage if reasonable care is taken. Most sensors are operated in the constant temperature mode.

PRINCIPLE OF OPERATION

Based on convective heat transfer from a heated sensing element, possessing temperature coefficient of resistance .

Hot-wire anemometers have been used for many years in the study of laminar, transitional and turbulent boundary layer flows and much of our current understanding of the physics of boundary layer transition has come solely from hot-wire measurements. Thermal anemometers are also ideally suited to the measurement of unsteady flows such as those that arise behind rotating blade rows when the flow is viewed in the stationary frame of reference. By a transformation of co-ordinates, the time-history of the flow behind a rotor can be converted into a pitch-wise variation in the relative frame so that it is possible to determine the structure of the rotor relative exit flow. Until the advent of laser anemometry or rotating frame instrumentation, this was the only available technique for the acquisition of rotating frame data.

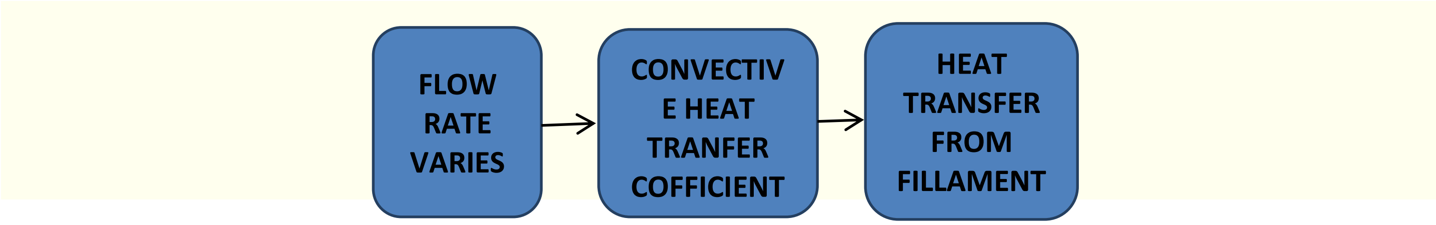

Fig.1- Block Diagram of Fluid Flow Hot Wire Sensor

3. HOT WIRE EQUATION

To examine the behaviour of the hot wire, the general hot wire equation must first be derived. This equation will be used to examine both the steady state response of the hot wire, discussed here, and its frequency response, discussed later. By considering a small circular element of the hot wire, Figure.2, an energy balance can be performed, assuming a uniform temperature over its cross-section:

$$I^2\delta R_w = \rho_w C_w \frac{\partial T_w}{\partial t} A\delta x + K_w A \frac{\partial T_w}{\partial x} + h\pi d(T_w - \eta T_0)\delta x - K_w A\left(\frac{\partial T_w}{\partial x} + \frac{\partial^2 T_w}{\partial x^2}\delta x\right) + \sigma\varepsilon(T_w^4 - T_{sur}^4)\pi d\delta x \quad (1)$$

This can be simplified, **Højstrup et al., 1976**, to give the general hot wire equation :

$$K_1 \frac{\partial T_w}{\partial t} = \frac{\partial^2 T_w}{\partial x^2} - \beta_1 T_w + K_2 T_a - K_3 \quad (2)$$

if radiation is neglected. The constants are given by:

$$K_1 = \frac{\rho_w C_w}{K_w} \quad (3)$$

$$\beta_1 = \frac{h\pi d}{K_w A} - \frac{\alpha I^2 \rho_{ref}}{K_w A^2}, \quad (4)$$

$$K_2 = \frac{h\pi d}{K_w A} \quad (5)$$

and

$$K_3 = \frac{I^2 \rho_{ref}}{K_w A^2}(\alpha T_{ref} - 1). \quad (6)$$

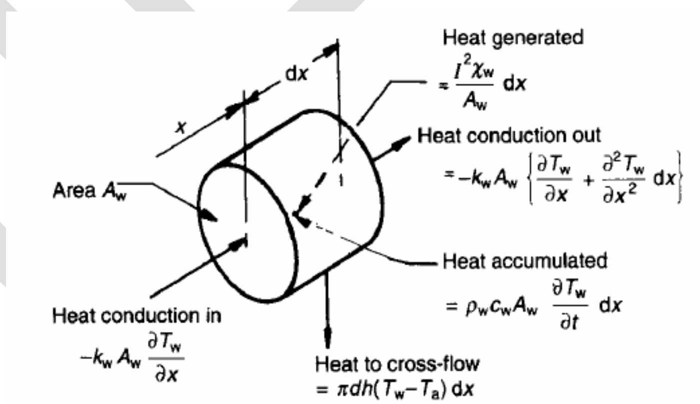

Fig.2-Heat Balance for an Incremental Element

A heat balance can then be performed over the whole wire, assuming that the flow conditions are uniform over the wire:

$$\overline{I}^2 R_w = \overline{H}cond + \overline{H}conv \quad (7)$$

The two heat transfer components can be found from the flow conditions and the wire temperature distribution:

$$\overline{H_{conv}} = 2l\pi d\bar{h}(T_m - \overline{T_a}), \quad (8)$$

$$\overline{H_{cond}} = 2K_w A \left|\frac{\partial \overline{T_w}}{\partial x}\right|_{x=1}, \quad (9)$$

To give a steady state heat transfer equation:

$$\overline{I}^2 R_w = 2\pi \overline{h_c} dl(T_m - \overline{T_a}), \quad (10)$$

HOT WIRE ANEMOMETER DESIGN

A fluid flow measurement using constant temperature hot wire anemometer is show in fig. 5. The input stage consist of M1 and M2 and the baising current is provided by M3 and M4 and the dc baising current is given 1nA.The output port Vout is connected to M10 and M12 transistor.

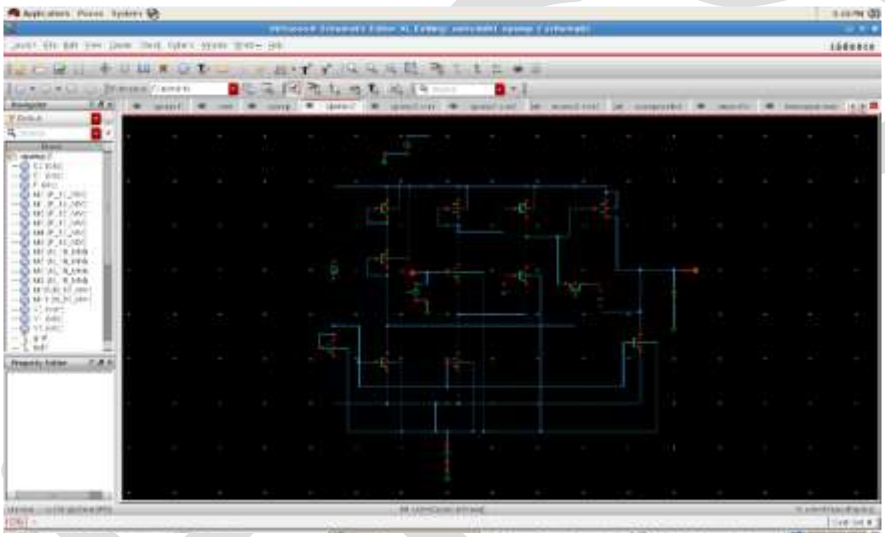

Fig.3-Schematic of CTA

The table- 1 show the dimension of each transistor in the circuit. The input transistor M1 and M2 are drawn with identical sizes and their width to length ratio as $\left(W/_L\right)_1$. similarly transistors M8 and M9 are same size $\left(W/_L\right)_8$. The PMOS current transistors M3, M4, M5 and M8 are same size $\left(W/_L\right)_3$.

Table 1: W/L Of CTA

Transistors	$\left(W/_L\right)$ (μm)
M1, M2	$^{50}/_{0.18}$
M3, M4, M5, M8, M9	$^{4}/_{0.18}$
M6, M7	$^{1}/_{0.18}$
M10	$^{30}/_{0.18}$
M11	$^{50}/_{0.18}$
M12	$^{45}/_{0.18}$

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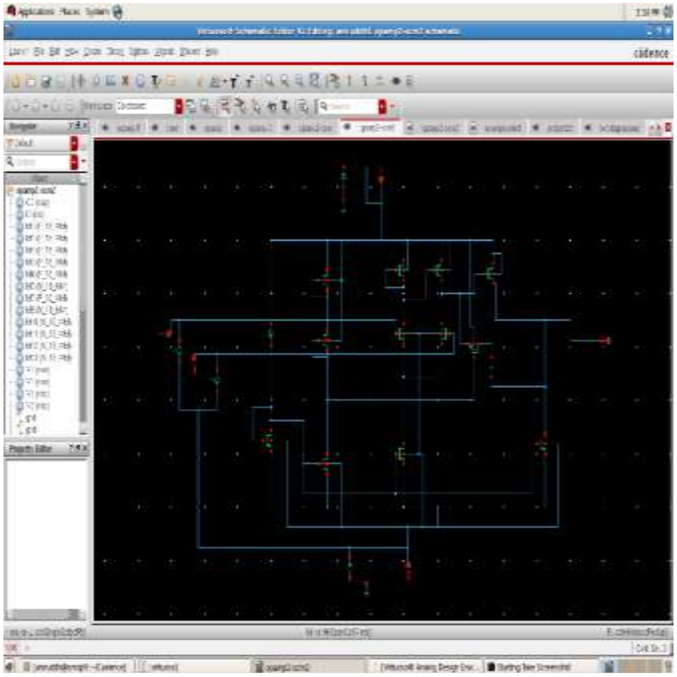

Fig.4-Common mode supply

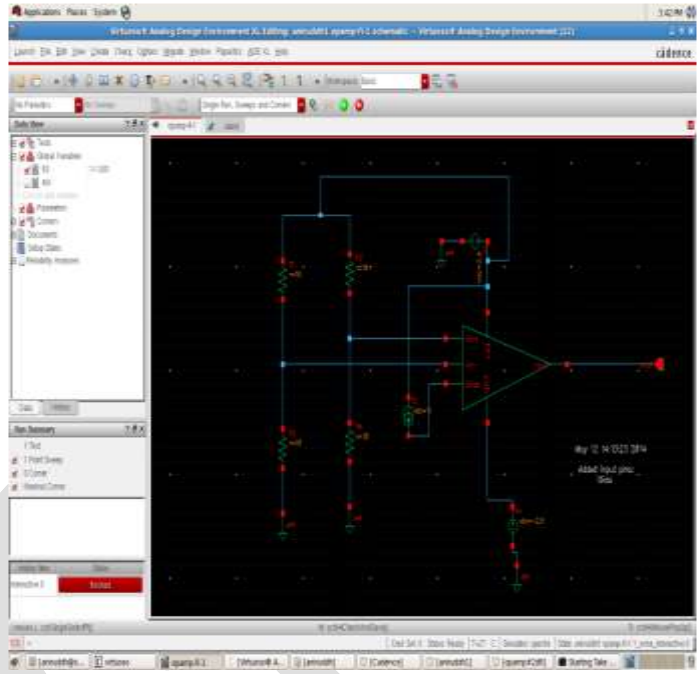

Fig.5- Fluid Flow Measurement Using Constant Temperature Hot Wire Anemometer

SIMULATION AND RESULT

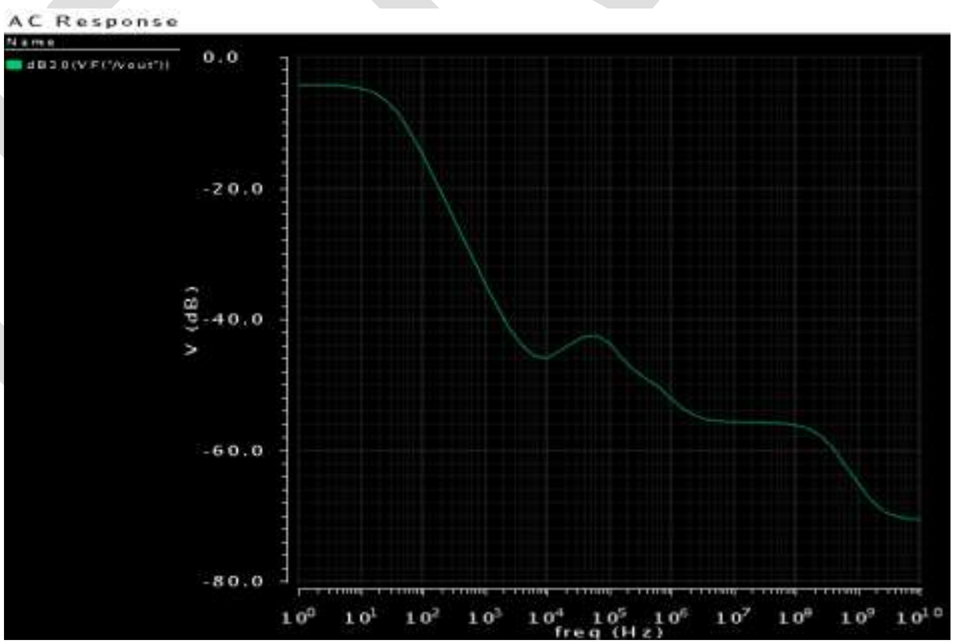

Fig.6-Output of commom mode input supply

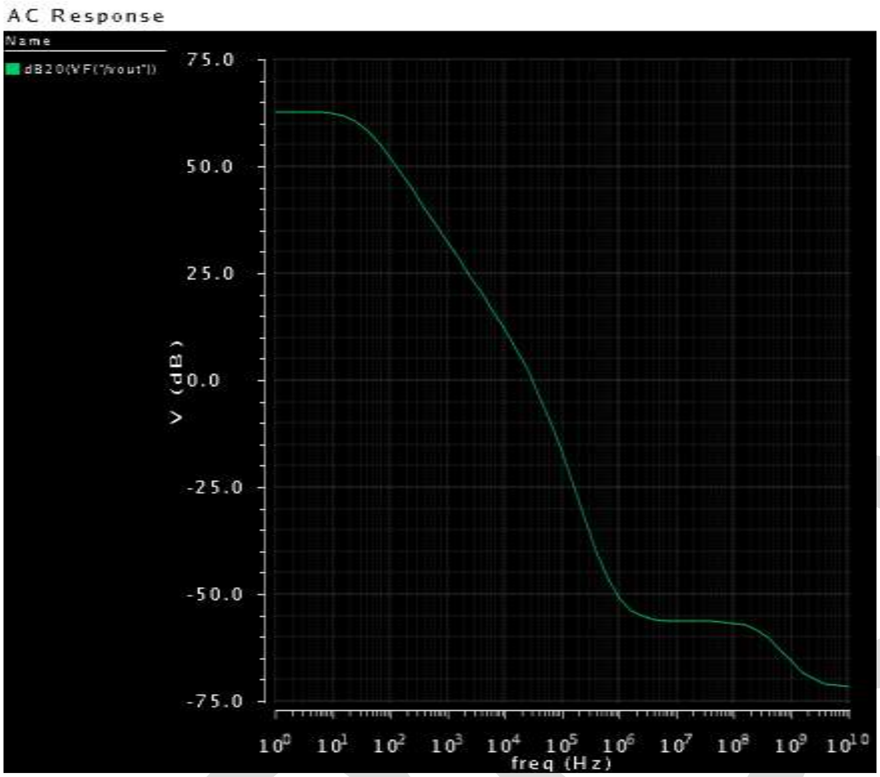

Fig.7-output of differential mode input in db

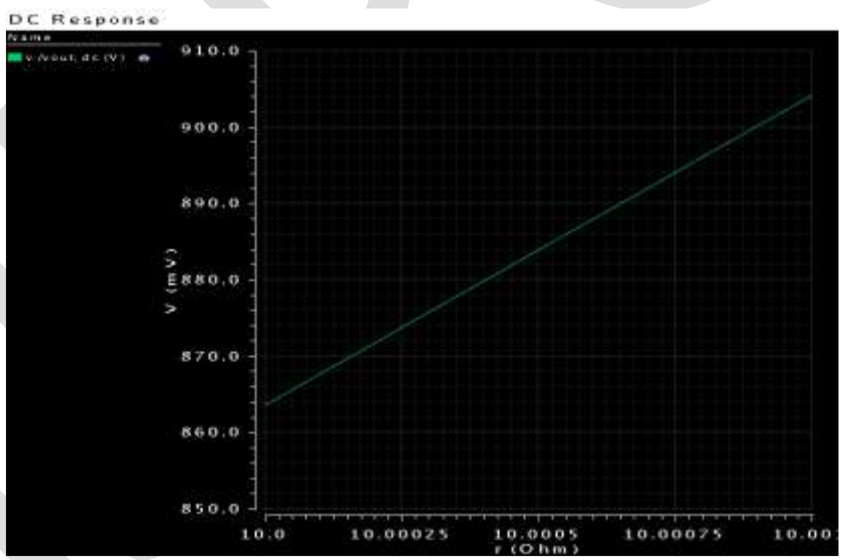

Fig.8- Output result

CONCLUSION

In this paper an Fluid Flow Measurement Using Constant Temperature Hot Wire Anemometer using on 0.18 µm technology proposed.The input can vary in the range of microvolts. Therefore the simulation result with 64.2dB value of gain, 70dB value of CMRR, and 400Hz bandwidth are obtained. These result demonstrate that the proposed circuit can be used to develop an integrated circuit.The output obtain is in milivolts and then amplify.

REFERENCES:

[1] Anderson, C. S., Semercigil, S. E. and Turan, Ö. F., 2003, "Local Structural Modifications for Hot-Wire Probe Design", Experimental Thermal and Fluid Science, Vol.27, pp. 193-198.

[2] Brunn, H. H., 1971, "Linearization and hot wire anemometry", Journal of Physics & Scientific Instruments, Vol.4, pp. 815-820.

[3] Bruun, H. H., 1995, "Hot-Wire Anemometry-Principles and Signal Analysis", Oxford Science Publications, New York.

[4] Bruun, H. H., Khan, M. A., Al-Kayiem, H. H. and Fardad, A. A., 1988, "Velocity Calibration Relationships for Hot-Wire Anemometry", Journal of Physics & Scientific Instruments, Vol.21, pp. 225-232.

[5] Citriniti, J. H., Taulbee, K. D. and Woodward, S. H., 1994, "Design of Multiple Channel Hot Wire Anemometers", Fluid Measurement and Instrumentation, Vol.183, USA, pp. 67-73.

[6] Eguti, C. S. A.; Woiski, E. R. and Vieira, E. D R., 2002, "A Laboratory Class for Introducing Hot-wire Anemometry in a Mechanical Engineering Course, Proceedings (in CD ROM) of the ENCIT 2002 VIII Brazilian Congress of Thermal Science and Engineering , Paper code: CIT02-0411, October, 15 – 18 – Caxambu, MG.

[7] Goldstein, R. J., 1983, "Fluid Mechanics Measurements", Hemisphere Publishing Corp., 630 p. Gonçalves, H. C., 2001, "Determinação Experimental da Freqüência de Emissão de Vórtices de Corpos Rombudos", Master of science dissertation, Unesp – Ilha Solteira, 200p.

[8] Lekakis I., 1996, "Calibration and Signal Interpretation for Single and Multiple Hot-wire/hot-filme Probes", Measurement. Science and Technology, Vol. 7, pp.1313-1333.

[9] Lomas, C. G., 1986, "Fundamentals of the Hot-wire Anemometry", Cambridge University Press.

[10] Menut, P. M., 1998, "Anemometria de Fio-quente", Proceedings of the First Spring Schools of Transition and Turbulence, (A. P. S. Freire ed.), Rio de Janeiro, pp.235-272.

[11] Möller, S. V., 2000, "Experimentação em turbulência", Proceedings of the Second Spring Schools of Transition and Turbulence, (A. Silveira Neto ed.), Uberlândia, MG, pp.63-97.

[12] Perry, A. E., 1982, "Hot-Wire Anemometry", Oxford University Press, New York, 185 p.

[13] Persen, L. N. and Saetran, L. R., 1984, "Hot-film Measurements in a Water Tunnel", Journal of Hydraulic Research, vol.21, no. 4, pp. 379-387.

[14] Sasayama, T., Hirayama, T., Amano, M., Sakamoto, S., Miki, M., Nishimura, Y. and Ueno, S., 1983, "A New Electronic Engine Control Using a Hot-wire Airflow Sensor" *SAE Paper* 820323, 1983.

[15] Vieira, E. D. R., 2000, "A Laboratory Class for Introducing Hot-Wire Anemometry", proceedings of the ICECE 2000 International Conference on Engineering and Computer Education, de 27 a 30 de agosto de 2000, São Paulo, SP.

[16] Weidman, P. D. & Browand, F. K., 1975, "Analysis of a Simple Circuit for Constant Temperature Anemometry", Journal of Physics & Scientific Instruments, Vol.8, pp. 553-560